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REDSHIFTS IN STELLAR TRANSITION REGIONS

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ABSTRACT We present moderate resolution GHRS spectra of the stars Procyon (F5 IV-V), AU Mic (M0 Ve), β Gem (K0 III), Capella (G0 III + G8 III), α TrA (K2 II-III), and β Dra (G2 II-Ib) to study the phenomenon of redshifted transition region lines first observed by IUE. Our GHRS data show redshifts for all of these stars except α TrA, but we find no correlation between redshift and stellar activity.

Using high dispersion IUE spectra of six active late-type stars, Ayres et al. (1983) discovered that transition region lines are redshifted relative to the photosphere. Redshifts are typically seen over strong magnetic regions on the Sun and are usually explained by the emission measure of downflowing plasma in magnetic flux tubes exceeding that of the upflowing material.

To further understand this phenomenon, we have obtained HST/GHRS moderate resolution spectra ($\lambda/\Delta\lambda \approx 20,000$) of six stars. The data consist of profiles of the C IV, Si IV, Si III], and C III] lines formed at temperatures of 30,000–100,000 K. We fit each of the emission lines with a single Gaussian. In the fitting process, this Gaussian was convolved with the instrumental profile of the GHRS to match the line profiles. The results of these fits are given in the following tables. In many cases single Gaussians did not fit the observed profiles very well, especially in the Si IV and C IV lines of AU Mic, Capella, and α TrA. These lines require a second broad Gaussian that Linsky and Wood (1994) interpret as analogous to solar "explosive events" that probably occur when magnetic fields reconnect. Nevertheless, single-Gaussian fits do provide a reasonably accurate measurement of the line centroids.

The measured velocities for each transition region line shown in the tables are often quite different. For example, the relatively active evolved stars (Capella, α TrA, and β Dra) have C IV 1548.2 Å profiles that appear to be significantly less redshifted than the C IV 1550.8 Å profiles. We believe that such differences are real rather than due to random errors, although we have no explanation for these differences at this time. Nevertheless, we take flux-weighted averages of the individual line velocities to obtain a single value for the transition region line velocity for each star. These averages and their 1σ errors are displayed in the tables along with the photospheric radial velocities. For Capella, the radial velocity given is for the G0 star, which dominates the emission in the transition region lines (Linsky et al. 1994).

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Procyon (F5 IV-V, d=3.5 pc)

Ion	λ_{rest} (Å)	λ_{meas} (Å)	v (km s^{-1})	f (ergs cm^{-2} s^{-1})	FWHM (Å)
C IV	1548.202	1548.234	6.2	5.36×10^{-12}	0.410
C IV	1550.774	1550.794	3.9	2.96×10^{-12}	0.416
Si IV	1393.755	1393.762	1.5	2.15×10^{-12}	0.389
Si IV	1402.770	1402.779	1.9	1.16×10^{-12}	0.364
Flux-weighted average			4.3 ± 2.2		
Stellar photo. rad. vel.			-3.0		

AU Mic (M0 Ve, d=9.3 pc)

Ion	λ_{rest} (Å)	λ_{meas} (Å)	v (km s^{-1})	f (ergs cm^{-2} s^{-1})	FWHM (Å)
Si IV	1393.755	1393.757	0.4	9.32×10^{-14}	0.421
Si IV	1402.770	1402.768	-0.4	4.67×10^{-14}	0.390
C IV	1548.202	1548.223	4.1	2.19×10^{-13}	0.350
C IV	1550.774	1550.776	0.4	1.21×10^{-13}	0.305
Flux-weighted average			2.0 ± 2.2		
Stellar photo. rad. vel.			-2.1		

β Gem (K0 III, d=10.0 pc)

Ion	λ_{rest} (Å)	λ_{meas} (Å)	v (km s^{-1})	f (ergs cm^{-2} s^{-1})	FWHM (Å)
Si IV	1393.755	1393.891	29.3	3.09×10^{-14}	0.243
Si IV	1402.770	1402.842	15.4	1.34×10^{-14}	0.177
C IV	1548.202	1548.285	16.1	5.74×10^{-14}	0.375
C IV	1550.774	1550.863	17.2	3.13×10^{-14}	0.425
Si III]	1892.030	1892.124	14.9	8.42×10^{-14}	0.385
C III]	1908.734	1908.790	8.8	4.87×10^{-14}	0.342
Flux-weighted average			16.0 ± 6.1		
Stellar photo. rad. vel.			3.0		

As expected, the flux-weighted averages mostly show redshifts with respect to the radial velocity of the stars. The hybrid-chromosphere star α TrA is the only star that has a flux-weighted average velocity consistent with no net redshift ($+2.5 \pm 7.0$ km s^{-1}) within the 1σ errors. This is not surprising since hybrid stars likely have very little magnetic field present on their surfaces. The redshifts observed for the other stars are: Procyon ($+7.3 \pm 2.2$ km s^{-1}), AU Mic ($+4.1 \pm 2.2$ km s^{-1}), β Gem ($+13.0 \pm 6.1$ km s^{-1}), Capella ($+23.2 \pm 5.1$ km s^{-1}), and β Dra ($+6.4 \pm 4.4$ km s^{-1}). For comparison, the shift of the four listed transition region lines of β Dra obtained by Ayres et al. (1988) using IUE is $+6.2 \pm 7.0$ km s^{-1}. We find no correlation of redshift with activity, as the relatively inactive stars, Procyon and β Gem, have fairly strong redshifts, and the very active M dwarf, AU Mic, has only a small redshift.

Capella (G0 III + G8 III, d=12.5 pc)

Ion	λ_{rest} (Å)	λ_{meas} (Å)	v (km s^{-1})	f (ergs cm^{-2} s^{-1})	FWHM (Å)
Si IV	1393.755	1393.918	35.1	1.21×10^{-11}	0.834
Si IV	1402.770	1402.885	24.6	6.93×10^{-12}	0.805
C IV	1548.202	1548.321	23.1	2.86×10^{-11}	1.188
C IV	1550.774	1550.930	30.2	1.59×10^{-11}	0.955
Si III]	1892.030	1892.167	21.7	2.63×10^{-11}	0.665
C III]	1908.734	1908.869	21.2	9.87×10^{-12}	0.534
Flux-weighted average			25.2 ± 5.1		
Stellar photo. rad. vel.			2.0		

α TrA (K2 II-III, d$\sim$40 pc)

Ion	λ_{rest} (Å)	λ_{meas} (Å)	v (km s^{-1})	f (ergs cm^{-2} s^{-1})	FWHM (Å)
C IV	1548.202	1548.157	-8.7	2.81×10^{-13}	0.848
C IV	1550.774	1550.819	8.7	1.64×10^{-13}	0.687
Si III]	1892.030	1892.040	1.6	2.70×10^{-13}	0.566
C III]	1908.734	1908.737	0.5	2.17×10^{-13}	0.424
Flux-weighted average			-0.5 ± 7.0		
Stellar photo. rad. vel.			-3.0		

β Dra (G2 II-Ib, d=77 pc)

Ion	λ_{rest} (Å)	λ_{meas} (Å)	v (km s^{-1})	f (ergs cm^{-2} s^{-1})	FWHM (Å)
C IV	1548.202	1548.121	-15.7	1.46×10^{-12}	0.952
C IV	1550.774	1550.747	-5.2	7.79×10^{-13}	0.724
Si III]	1892.030	1891.944	-13.6	1.65×10^{-12}	0.549
C III]	1908.734	1908.628	-16.7	1.09×10^{-12}	0.452
Flux-weighted average			-13.6 ± 4.4		
Stellar photo. rad. vel.			-20.0		

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